Adaptive Snow Plow Routing Using Genetic Algorithm Artificial Intelligence

- James Zollweg, Ph.D.
  - Associate Professor, The College at Brockport
  - jzollweg@brockport.edu

  - Survivor of countless snowy winters in the vicinity of the three snowiest major cities in the USA

Learning Outcomes

- Broaden understanding of complexities and considerations involved in routing snowplows
- Recognize the potential of advanced computing technologies to reduce costs and improve service
- Consider the possibility of routings that vary from event-to-event depending on conditions (i.e. adaptive)

Snowplow Routing: the obvious

- Snow removal is a $3 Billion yearly expense in the USA, and is among the largest expenditures for many municipalities at a time when budgets are strained more than ever.
- Calculating optimum (or even near optimum) routes for a fleet of snow removal vehicles is extraordinarily difficult

Snowplow Routing: complications

- Unlike other vehicle routing problems, every street must be covered, in both directions
- Street segments have varying priorities – cul-de-sac, local, collector, arterial
- Snowplows are especially difficult vehicles to operate – U-turns and left turns are disadvantageous
- Differences in intensity and duration of snowfall create vastly differing needs for snow removal
- Road networks are complicated and illogical

Snowplow Routing: characteristics of great solutions

- Minimizes total cost (directly related to miles driven)
  - Reduce ‘deadheading’
- Finishes job in acceptable length of time
  - Balance workload among operators
- Prioritize more ‘important’ roads
  - Time of day?
- Minimizes number of trucks used
  - Tradeoff between efficiency and completion time
- Avoid U-turns and left turns
- Closely linked to a GIS for effective I/O

Solutions to snowplow routing?

- The vehicle routing problem (VRP) is a long-studied topic with many variations and approaches
  - Traveling salesman problem
  - (Rural) Chinese postman problem
  - Capacitated VRP (road salt problem)
  - VRP with Pickup and Delivery
- Much more difficult is the multiple vehicle routing problem (mVRP)

mVRP requires **allocation**

- Need to divide the entire municipality into service areas, each handled by one plow
  - How to do this?
  - Can the workload be balanced among operators?
  - Since the process of allocation reduces the solution space, does it limit the efficiency of the final solution?

mVRP requires **allocation**

- Need to divide the entire municipality into service areas, each handled by one plow
  - How to do this?
  - Can the workload be balanced among operators?
  - Since the process of allocation reduces the solution space, does it limit the efficiency of the final solution?

YES!

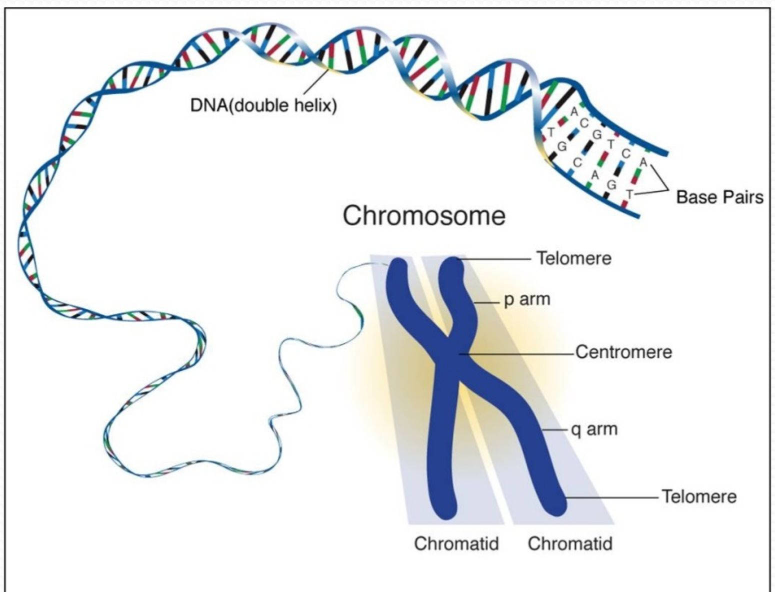
What to do?

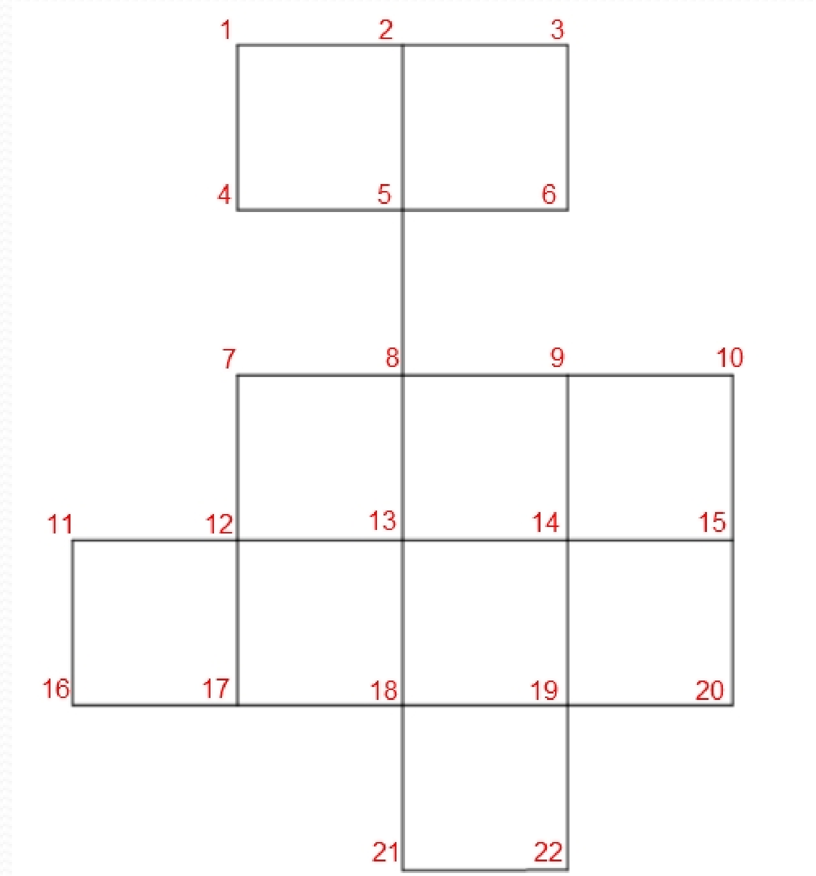
- Develop a method by which allocation and routing progress (evolve) simultaneously – A Genetic Algorithm

Genetic Algorithm

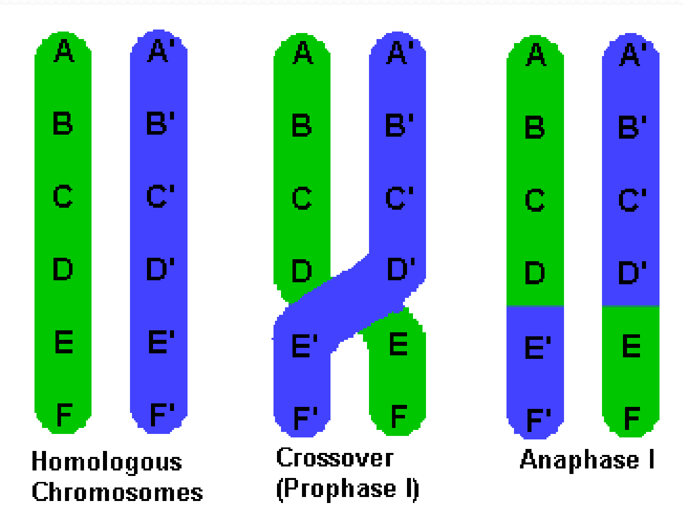
- Possible solutions are 'encoded' as if they were chromosomes

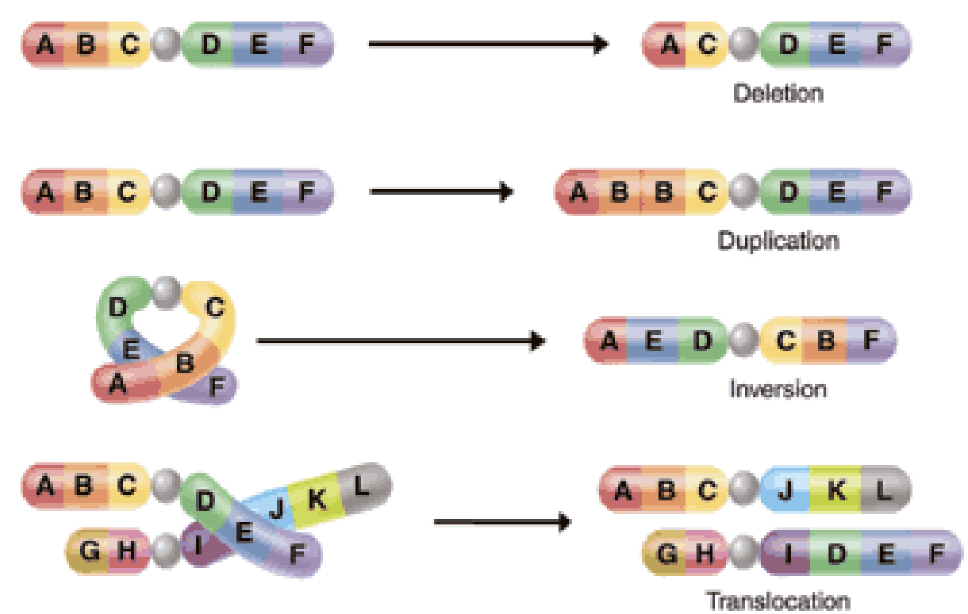
0-10-15-20-19-22-21-18-19-20-15-14-19-18-21-22-19-14-15-10-9-14-13-18-17-16-11-1
2-17-18-13-14-9-8-13-12-11-16-17-12-13-8-5-4-1-2-3-6-5-2-1-4-5-6-3-2-5-8-7-12-7-
8-9-10-0





Crossover, Mutation





Chromosomal Mutations Chromosomal mutations involve changes in whole chromosomes.

Genetic Algorithms applied

- An initial population of candidate solutions is created
  - In case of snow plow routing, plows are allowed random travel around town until all roads are plowed
  - Don't need to be good, just complete
- A "fitness test" is applied to each solution
- The best solutions are "bred" to generate the next generation of solutions
- REPEAT

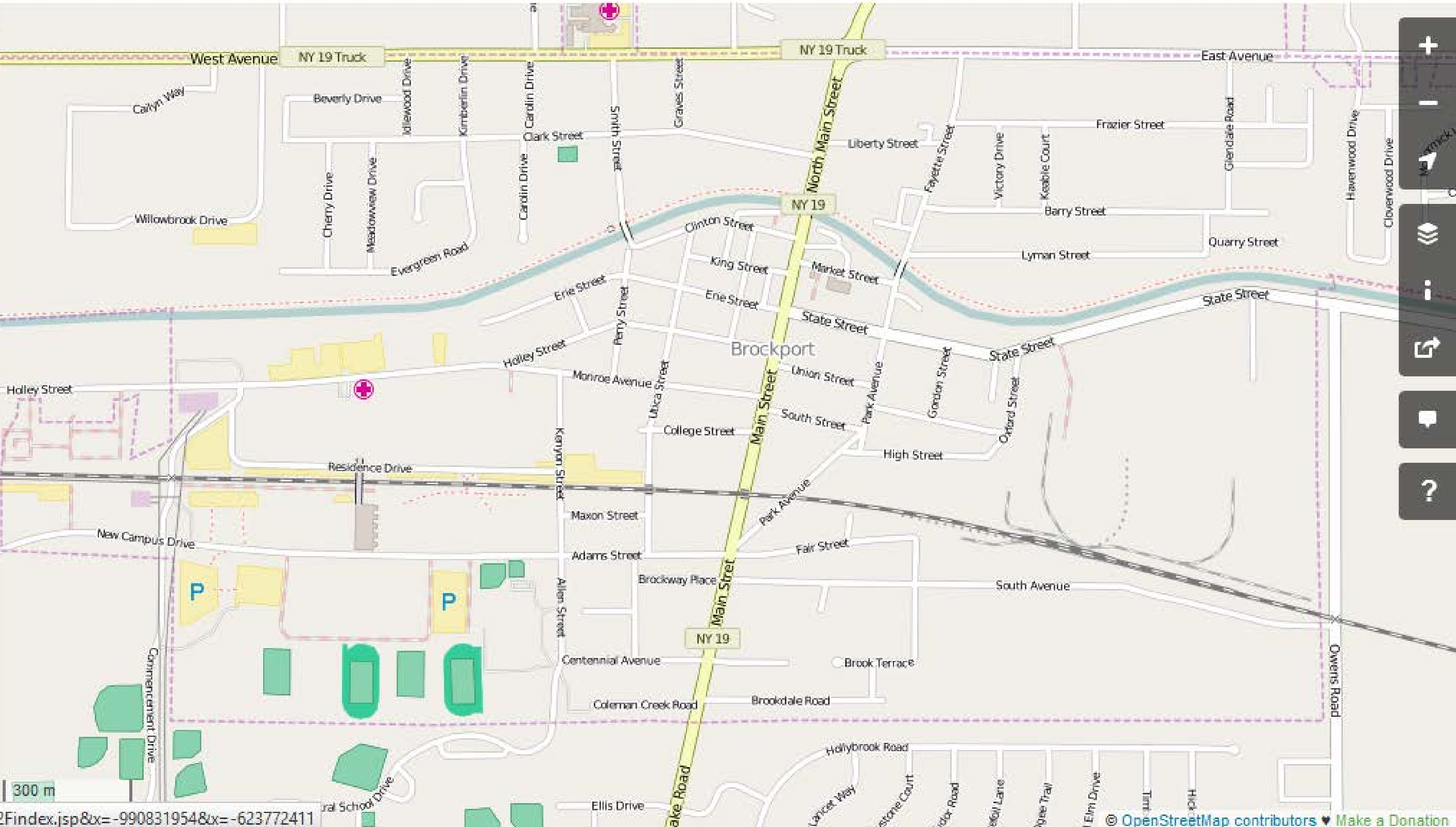
Empirical evidence

- Numerous 'tiny-towns' were divided up into service areas in a variety of ways – then each service area was routed
- Also, the genetic algorithm solution was applied to each tiny-town
- In each case, the genetic algorithm solution produced a better result

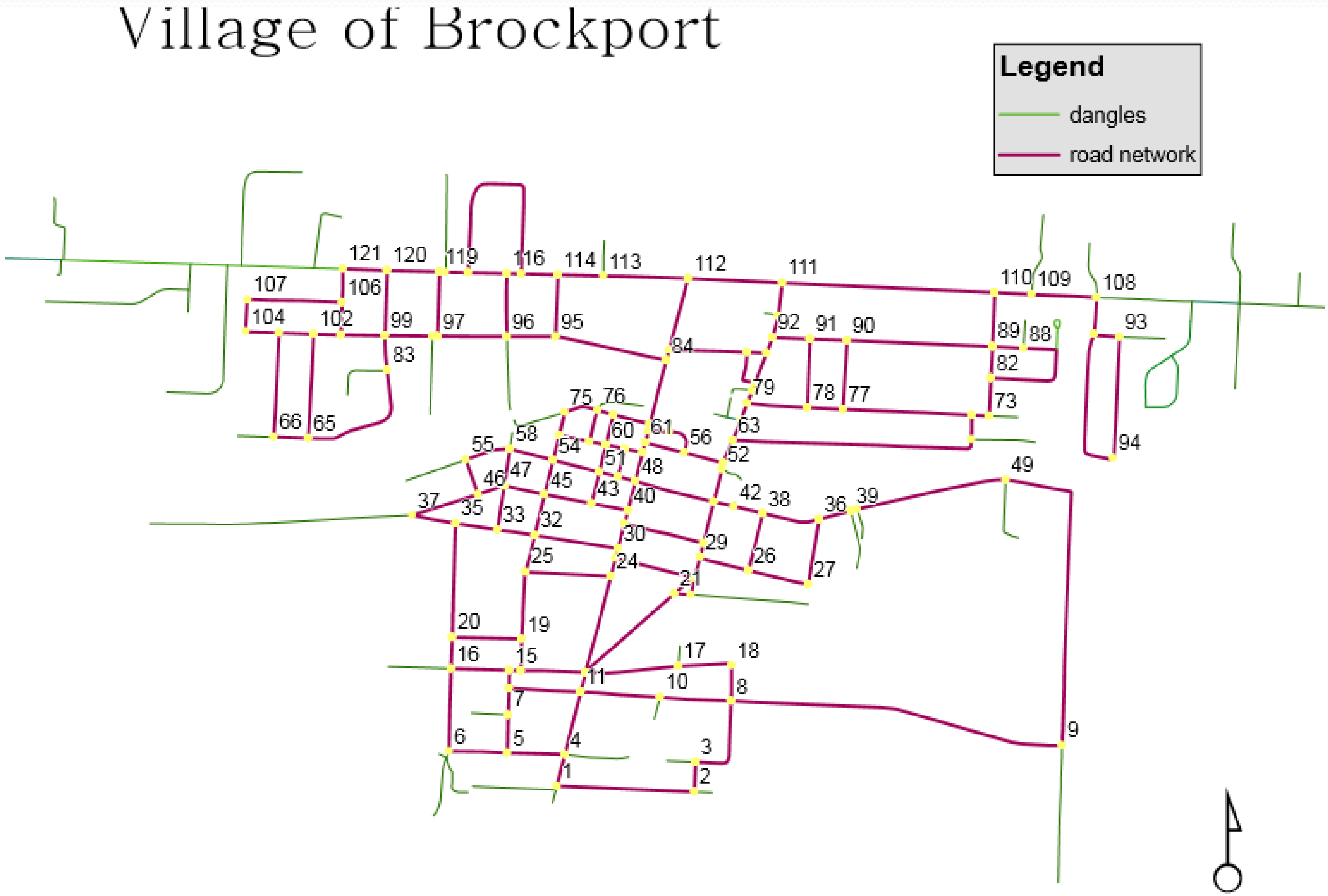
Results - Town of Parma

Algorithm Used	Partitions	Total Distance Covered (mtrs)	# of U-turns	# of Repeated Road Segments
Hand-Computed by Planners	6	345,153	45	2
GA (4 partitions)	NE NW SW SE Total	53,262 81,260 57,199 81,234 272,955	10 8 11 8 37	0 2 0 0 2
GA (1 Partition)	Whole town	274,830	38	34

Feedstock - OpenStreetMap



V. of Brockport – GIS roads data set



Plow Route #4

SHOW ANIMATION

How this might be used

- Run the GA SPR at the start of every event to optimize the number of plows and their routing
  - Snowfall rate
  - Expected storm duration
  - Time of day
- Generate turn-by-turn GPS instructions for operators

Learning Outcomes

- Broaden understanding of complexities and considerations involved in routing snowplows
- Recognize the potential of advanced computing technologies to reduce costs and improve service
- Consider the possibility of routings that vary from event-to-event depending on conditions (i.e. adaptive)